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(71) Applicant: ACCUMETRICS, INC. [US/US]; 3985–B Sorrento Valley Road, San Diego, CA 92121 (US).

(72) Inventors: DURBIN, Dennis, A.; 711 Marsolan Avenue, Solana Beach, CA 92075 (US). LEE, Theodore, T.; P.O. Box 9405, Rancho Santa Fe, CA 92067 (US). RATNIKOV, Boris, I.; 10876 Avenida de los Lobos, San Diego, CA 92127 (US). HILLMAN, Robert, S.; 4963 Hidden Dune Court, San Diego, CA 92130 (US). SMITH, Jeffrey, W.; 12602–6 Carmel Country Road, San Diego, CA 92130 (US).

(74) Agent: CHOW, Ping Y.; Heller, Ehrman, White & McAuliffe, 3401 Hillview Avenue A2–200, Palo Alto, CA 94304 (US).

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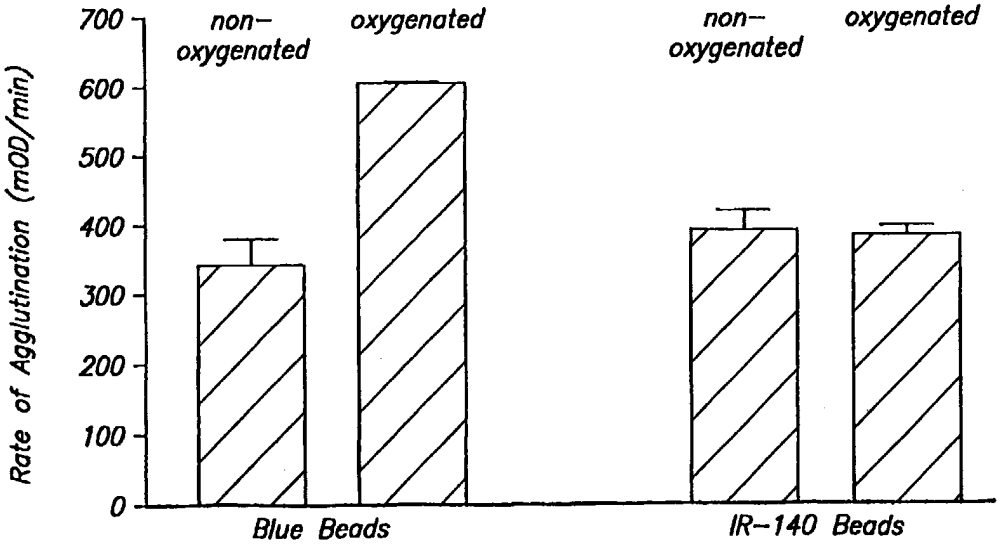


(57) Abstract

Methodology is provided for determining a characteristic of a sample, wherein problems associated with interference from whole blood, and oxygenated whole blood in particular, are avoided. Particularly, small particles are employed to which is bound a reagent, which interacts directly or indirectly, with a component related to the characteristic to be determined, which particles absorb in the infrared. By employing a protocol which results in the agglutination of the particles, the change in light absorption characteristics of the sample can be directly correlated with the presence, and as appropriate, function of the component related to the characteristic of interest in the sample.

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# AGGLUTRIMETRIC ASSAYS IN BLOOD

## INTRODUCTION

### Background

The medical industry has become increasingly dependent upon techniques for measuring various entities in physiological fluids in order to be able to determine the health status of an individual, dosage level for drugs, use of illegal drugs, genomic sequences, and the like. Thus, the capability of taking a physiological sample and rapidly analyzing it for the presence of a particular component has made medical therapies more efficient and increasingly successful.

In many instances, one wishes to use whole blood as a source to diagnose a patient's health or to monitor the efficacy of drugs that have been administered to the patient. However, blood as a source for the determination of these parameters has many deficiencies. Among its deficiencies when used directly or even when diluted with buffer are: blood rapidly coagulates, blood contains a large number of light absorbing and florescent substances; blood exhibits variations in composition, its characteristics can change in relation to the reagents used in the assays; and blood exhibits variations in the presence or absence of oxygen. While these properties complicate the use of blood as a sample for diagnostic purposes, various techniques have been employed to reduce or eliminate these problems including, for example, high dilution, addition of anticoagulants, separation of blood into plasma and its cellular components, and the like. During such manipulations, however, great care must be taken to avoid lysis of red blood cells to avoid the release of hemoglobin, which can interfere with diagnostic assays. Despite the problems associated with the use of blood as the sample medium, in many instances, blood is the only source which

provides the information of interest. Therefore, identifying ways of using whole blood, while diminishing the interference from its constituents is highly desirable.

There is, therefore, substantial interest in devising new approaches for using and manipulating blood for diagnostic purposes. One area that is of particular interest is the use of blood for the assessment of platelet function. The role of platelets in mammalian physiology is extraordinarily diverse, but their primary role is in promoting thrombus formation. In many situations, one wishes to evaluate the ability of the blood to clot, a parameter that is frequently mediated by the ability of platelets to adhere and/or aggregate. Thus, one may wish to assess the adhesive functions of platelets. For example, one may wish to know whether to administer drugs that will block, or promote, clot formation, or one may need to detect deficiencies in platelet function prior to surgical procedures. In other instances one may be interested in evaluating the effectiveness of a platelet inhibitor that is being tested, as a new drug, or is being used as approved clinical treatment in a patient. Novel diagnostic assays for performing the above will, therefore, prove valuable.

Relevant Literature

U.S. Patent No. 5,455,228 and PCT Application No. WO96/10749 describe a peptide resistant ligand and a platelet blockade assay, respectively. See also, Coller, B.S. Platelets in cardiovascular thrombosis and thrombolysis. In: Fozzard et al., eds. *The Heart and Cardiovascular System,* 2nd ed., New York, NY: Raven Press; 1992:219-273. For a description of infrared absorbing dyes, see Fabian et al., *Chem. Rev.* 92:1196-1226 (1992).

Other techniques which have been taught for determining platelets and/or platelet function include: PCT applications WO94/12664; WO94/22018; WO92/08982; WO89/00200; U.S. Patent Nos. 5,427,913; 5,306,632; 5,523,238; 5,266,462; 5, 246, 832; 5,114,842; and EPA 0 165 68. Articles of interest include: Beer et al., Immobilized Arg-Gly-Asp (RGD) peptides of varying lengths as structural probes of the platelet glycoprotein IIb/IIIa receptor. *Blood* 79:117-128 (1992). Coller et al., Collagen-platelet interactions: Evidence for a direct interaction of collagen with platelet GPIa/IIa and an indirect interaction with platelet GPIIb-IIIa mediated by adhesive proteins. *Blood* 74:182-192 (1989); Coller et al., Studies of activated GPIIb-

IIIa receptors on the luminal surface of adherent platelets. *J. Clin Invest.* 92:2796-2806 (1993); and Pfueller et al., Role of plasma proteins in the interaction of human platelets with particles. *Thrombosis Research* 12:979-990 (1978).

## SUMMARY OF THE INVENTION

An agglutimetric assay is described which employs particles that absorb light in the infrared region. Aggregation of particles is detected by changes in infrared absorption of the sample media. The assay may be used to determine the presence of a component of interest, the function of that component, or determine the amount of the component. The methodology permits the use of whole blood or slightly diluted blood, rather than plasma. The method involves mixing the particle reagent, any additional reagents as appropriate, and the sample and then measuring the change in infrared light absorption of the medium. The result may be compared to controls for quantitative determination.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a graph depicting the effect of oxygenation of blood on the baseline rates obtained with particles that absorb in the visible range, or in the infrared range. Because the oxygenation of blood changes the hemoglobin absorption profile, which alters the absorbance of the blood in the visible range, there is significant interference with the assay. Hence, with blue beads oxygenation of blood causes an artifactual increase in the observed rates of agglutination. In contrast, using particles which absorb light in the IR range, oxygenation of blood has no effect. Hence the rates that are reported are independent of the oxygenation of the blood.

FIG.2 is a graph of the results of a rapid platelet function assay (RPFA) of Searle compound 54701B. The RPFA was performed and maximum activity determined as described in the Experimental Section. The mean and individual results from six separate donors is shown in this and the subsequent figure.

FIG. 3 is a graph of the results of the optical platelet aggregation assay of Searle compound 54701B using 20$\mu$M ADP agonist. Optical platelet aggregation was performed as described in the Experimental Section. Results shown are the

maximum slope data (% change of aggregation/minute) and are not normalized values.

FIG. 4 is a graph comparing the results of platelet aggregation obtained using a commercially available system (platelet aggregometry) plotted against platelet activity obtained with RPFA. Two panels are shown, each depicts the RPFA performed with a different set of dyed particles. In the top panel, the particles absorb in the IR range. In the bottom panel, the particles absorb in the visible range. The data in the top graph are the mean and standard error obtained from dose response curve values performed on six subjects for three days. The correlation coefficient is 0.99 and there is minimal bias (0.4%) The data in the bottom graph are from an experiment performed in the same manner using beads dyed with a blue dye. The correlation coefficient is 0.94 and there is a significant bias present (10.7%).

FIG. 5 is a graph, showing neutralization of GPIIb/IIIa inhibitory compounds, Searle Compound 54701B and Searle Compound 57101A, by rabbit antisera raised against those compounds. Results shown are the normalized slope data (% baseline rate when no drug and no antisera were added).

FIG. 6 is a graph, showing reversal of GPIIb/IIIa inhibition by Gel Filtration of blood samples, treated with GPIIb/IIIa inhibitors. Results shown are normalized slope data (% baseline rate of untreated blood sample). X axis legend: 1- untreated blood, 2 - untreated blood after gel filtration, 3 - blood treated with 100 nM Searle Compound 54701B, 4 - blood treated with 100 nM Searle Compound 54701B after gel filtration, 5 - blood treated with 500 nM Searle Compound 57101B, 6 - blood treated with 500 nM Searle Compound 57101B after gel filtration.

FIG. 7 is a graph showing a Thrombin Induced Agglutination dose response curve. A 160 ul aliquot of mixture containing a known concentration of thrombin in a light-scattering medium (1% solids suspension of 0.5 um polystyrene microspheres in 10 mM HEPES 150 mM NaCl, 2 mg/ml BSA 0.05% Tween 20) to mimic light scattering characteristics of whole blood , was added to a plastic cuvette containing iso-TRAP and microparticles. The mechanical mixing cycle was activated for 1 minute with optical reading sampled at a rate of 16 per second. Microagglutination was determined by the rate of change of the optical density of the solution over at

fixed interval. The data are reported as the slope of thrombin-induced agglutination in mV/sec vs. the concentration of thrombin in the assay.

Fig. 8 illustrates the inhibition of thrombin-induced agglutination of IR beads by a Gly-Pro-Arg-Pro (GPRP) peptide.

## DESCRIPTION OF SPECIFIC EMBODIMENTS

In accordance with the subject invention, the character of a sample is determined by combining the sample with particles that absorb in the infrared, where the rate and/or extent of aggregation of the particles is modulated by the character of the sample. Normally, the character of the sample will be associated with the presence and amount of a component of interest. In other situations the character may be associated with the activity of the sample in relation to its effect on an event, e.g. clotting. Other reagents may also be present, depending upon the nature of the components and the protocol of the assay. After sufficient time for any aggregation to occur, the assay mixture is illuminated with infrared light and the change in absorption determined. The value obtained may be compared to a standard for a quantitative determination of the amount of component in the sample.

The method is flexible and can be used to assess several parameters, including the presence of a component in the sample, the character of the sample, or even the combined effect of several components in the sample on the penultimate agglutimetric reaction. However, for the purposes of the description, the description will refer to the component of interest and its functional activity, rather than the character of the sample.

Any sample can be used in the subject method. The method is particularly advantageous for those samples which contain entities that might interfere with spectrophotometric determination at wavelengths other than infrared. The sample may be any physiological fluid, environmental fluid, processing fluid, effluent or influx. The subject methodology finds immediate application with physiological fluids, more particularly whole blood or plasma. By using the subject methodology, less care in preparing the plasma is required, since released hemoglobin and other metal or non-metal porphyrins will have reduced interference in the methodology due to their reduced absorbance in the infrared range.

Particular samples that find use in the subject method may include, as indicated, blood, plasma, cerebrospinal fluid, saliva, urine, and the like, more particularly, those samples having an interfering substance that absorbs or emits light in the range of about 300nm to about 700nm. Therefore, the subject methodology finds use, particularly with whole blood, by employing infrared light, where the signal from the sample is not significantly affected by the variations in absorption resulting from changes in oxygenation of the sample.

The sample employed in the subject method may be subject to pre-treatment, depending upon the nature of the sample. Generally, the sample may be used without significant manipulation, however, samples may also be diluted, concentrated, extracted, chromatographed, electrophoresed, and the like. Desirably, there will be minimum sample manipulation. In accordance with the subject invention, whole blood may be used, which is diluted less than about 10-fold, usually diluted less than about 5-fold, preferably less than about 1-fold, and, more preferably less than about 0.5-fold. The blood will generally be modified to prevent coagulation, by using various anti-coagulants. Anti-coagulants that find use herein include citrate, heparin, thrombin inhibitors such as hirudin, hirulog, p-pack, argatroban, and the like. Conveniently, citrate is employed in a small volume in relation to the volume of the whole blood sample, generally less than about 25% v/v, usually less than about 10% v/v, and may be less than about 1% v/v. In cases where one or more component(s) of the system are citrate-sensitive, however, one may conveniently employ heparin or one or more of the direct thrombin inhibitors.

Any compound of interest can be employed which may serve to inhibit or enhance the aggregation of the particles. Thus, the compound of interest may be any compound which interacts, either directly or indirectly, with a compound on the surface of the particles, so as to enhance or inhibit aggregation, where indirectly intends that the compound of interest reacts directly or indirectly with a reagent which serves to enhance or inhibit aggregation. For indirect reaction, one may consider enzyme inhibitors. For example, a thrombin inhibitor would react with the thrombin to inhibit the reaction of thrombin with fibrinogen. Where the particles are coated with fibrinogen, the inhibitor would reduce the amount of aggregation by reducing the extent of reaction of the thrombin with the fibrinogen on the particles. Inhibitors of

other blood factors which ultimately affect the transformation of fibrinogen to fibrin would act similarly in an indirect manner.

Thus, the compounds of interest may be small molecules, generally from about 100-5000Dal, more usually from about 100-2000Dal, such as synthetic drugs, biocides, e.g. pesticides, herbicides, etc., antibiotics, naturally occurring ligands or fragments of naturally occurring compounds, amino acids, saccharides, lipids, nucleosides and nucleotides, and their oligomers, particularly oligopeptides, oligosaccharides or oligonucleotides, and combinations thereof.

Illustrative compounds of interest include drugs of abuse, such as tetrahydrocannabinol, morphine, heroin, cocaine, and methamphetamine, barbiturates, tranquilizers and antidepressants, e.g. librium, diazepams, and tricyclics, diphenylhydantoin, immunosuppressants, e.g. cyclosporine and FK506, cardiovascular drugs, e.g. digitonin, nitroglycerin, etc., clotting inhibitors, e.g. Warfarin, heparin, low molecular weight heparin, aggregation activators, e.g TRAP or iso-TRAP which will be useful for determining, for example, platelet loss during surgery and for the screening of platelet packs prior to administration, analgesics, anaesthetics, antihypertensive reagents, e.g. renin inhibitors, lipid A, toxins, IIb-IIIa antagonists including compounds such as RGD and KGD-based peptides and peptidomimetics, one subset of these compounds includes Searle compound 54701, Searle compound 57101, ReoPro (Centacor), Integrilin (Cor), Roche Ro440-3888, Hoechst S 1197, Merck L-738,167, TAK 029 (Tap Holdings), Boehringer Ingelheim BIBU 52ZW, ADP useful for measuring aspirin sensitivity and monitoring and at higher concentrations for determining, for example, platelet loss during surgery and for the screening of platelet packs prior to administration, collagen, arachidonic acid, and the like.

The compounds of interest may be macromolecular compounds, which will have a molecular weight of at least about 5kD, more usually at least 10kD, and generally less than about 1 million kD, more usually less than about 600,000 kD. These compounds may include various natural or synthetic polymers, such as polypeptides, nucleic acids, polysaccharides, lignins, polylipids, combinations, such as mucopolysaccharides, glycoproteins, sulfonated polysaccharides, lipopolysaccharides, and the like.

Illustrative macromolecular compounds include insulin, blood factors, e.g. Factor V, VI, VII, VIIIc, VIII vw, IX, X, X, XI and XII, soluble histocompatibility antigens, e.g. sHLA, ß-amyloid, HIV gp120 and p41, CD3, CD28, B7, glutamic acid dehydrogenase, tissue plasminogen activator, colony stimulating factors: G, M, and GM, perforins, complement proteins, bacterial and fungal proteins, protista proteins, viral proteins, and the like.

Finally, the compound of interest may be a combination of one or more different categories of compounds, such as viruses, organelles, such as mitochondria, prokaryotes and eukaryotes, such as bacteria, fungi, protista, chlamydia, mammalian cells, such as platelets, cancer cells, e.g. leukemia and lymphoma, and the like. Viruses of interest include HIV, HTLV, papilloma virus, herpes virus, hepatitis viruses, adenoviruses, rhinoviruses, and the like.

The particles that are employed in the subject method will generally be smaller than about 50 $\mu$, more usually smaller than about 25 $\mu$, usually being at least about 0.1 $\mu$, preferably from about 1-10 $\mu$, more preferably from about 2-8 $\mu$. The composition of the particle may be any convenient composition, such as bioglass, synthetic organic polymer, e.g. polyacrylonitrile, polystyrene, polycarbonate, polyacrylate, polymethacrylate, carbon-based, combinations thereof, or the like, or other material that itself absorbs in the infrared or can be made to do so with infrared absorbing dyes. For bioglass-based and organic polymer-based particles, the particle composition without the infrared absorbing dye will not absorb significantly over a broad range in the infrared region of interest, usually absorbing less than about 25% of the total light absorbed in that region compare to the particle doped with the infrared absorbing dye. Also, there will be many regions in the visual region in which the particle composition will be substantially transparent. Usually, at least 50 weight %, preferably at least about 75 weight %, will be of a size or diameter within the range indicated.

In a particularly preferred embodiment, the particles employed are carbon particles that fall within the size ranges indicated above and which may be either porous or non-porous. Carbon particles that find use may be spherical or non-spherical, preferably spherical, and generally absorb over a broad range in the infrared region without being doped with an infrared-absorbing dye. Like the particles described above, carbon particles may be modified in a variety of ways so as to allow

covalent or non-covalent attachment of various system components, e.g., proteins, thereto. Carbon particles that find use herein may be prepared using methodology known in the art or may be obtained commercially (Sigma Aldrich Supelco, Bellefonte, PA). In another embodiment, the particles are not carbon particles.

The particles that find use herein may be modified in a variety of ways. The particles may be chemically active or chemically activated by having functional groups present on the surface of the particles, or be coated with a compound, e.g. protein, which may serve to substantially irreversibly (under the conditions of the processing and assay) bind to a infrared-absorbing dye if one is employed and/or be involved in the aggregation of the particles. The coating compound may be a binding component, which will be involved in the aggregation of the particles, or other compound, usually being a protein. For coating the particle surface with a compound of interest, in the case where the particles themselves have chemically reactive functionalities on their surfaces or have sites that can be readily converted into chemically reactive functionalities, one may directly covalently attach the compound to the surface of the particles by covalent linkage to through these chemically reactive sites (see, e.g., U.S. Patent No. 5,503,933, issued to Afeyan et al.). One may also coat the particle surface with a functionalized or functionalizable latex composition that provides chemically reactive sites through which the compound may be covalently attached. Methods for preparing latex compositions and coating the surface of particles with such compositions are well known in the art (see, e.g., U.S. Patent No. 5,324,752). Alternatively, depending on the nature of the particles, the particles may not have or be made to have chemically active groups, but rather provide non-covalent binding of the compound by passive adsorption. In addition, infrared absorbing dyes that are stable under the conditions of formation of the particles, e.g. extrusion, may be mixed with the polymer prior to particle formation and the particle formed with the dye distributed throughout the particle.

A binding component may be bound to the particle surface which provides for aggregation of the particles. Particle aggregation may be a result of the interaction of the binding component with the same or a different component on another particle or with an agent in the medium, which agent may be the compound of interest, a member of a specific binding pair, or a catalytic agent, e.g. an enzyme, which interacts, usually

reacts, with the binding component to modify the binding component to cause aggregation. The specific binding pair will usually consist of the binding component and the compound of interest, a reagent which competes with the compound of interest for binding to the binding component, or a reagent which binds to the compound of interest. These may be illustrated by, for example, (1) an antigen and antibodies to the antigen as the binding component, (2) a dimer of the compound of interest binding to Fab as the binding component, and (3) fibrinogen and thrombin. The binding component bound to the surface of the particles will vary widely as to its nature, depending upon the compound of interest and the protocol that is employed.

The binding component may be a small molecule, as small molecules were described previously, or a higher molecular weight molecule, or even in some instances, combinations such as virus or cell fragments or intact viruses or cells. Any of the compounds previously discussed may serve as the binding component. In one group of assays employing specific binding pairs for aggregation, where one is interested in binding to naturally occurring or synthetic components of interests, specific receptors may be employed, such as naturally occurring receptors, e.g. enzymes, lectins, surface membrane proteins, etc., or antibodies, either antisera or monoclonal antibodies. In other assays, one may employ one member of a naturally occurring specific binding pair, such as fibrin (prepared in the assay medium from fibrinogen), which can bind to various proteins. The use of fibrinogen in conjunction with the platelet protein GPIIb/IIIa will be discussed in greater detail subsequently. In other embodiments, the binding component may be any of a number of different oligopeptides comprising the amino acid sequence RGD or KGD, or peptidomimetics thereof, having specificity for binding to the GPIIb/IIIa receptor or von Willebrand's factor or fragments thereof that are capable of being bound by specific receptor molecules. Various integrins may be used in conjunction with various adhesive proteins and vice versa. Antibodies may be assayed, where one could have the epitope which binds to the antibody bound to the particle. The epitope could be present as a small molecule, such as a synthetic organic molecule or an oligopeptide, or could be a polyepitopic molecule where one or more antibodies in the medium bind to the various epitopes of the antigen. Where the component of interest is monoepitopic, one may employ as a reagent a dimer or higher order of the

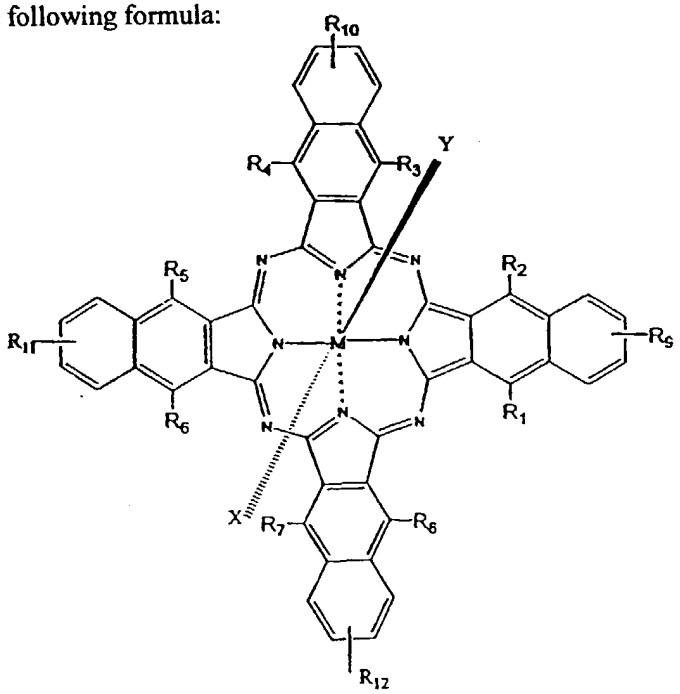
monoepitopic compound, which reagent will serve to cross-link. Anti-idiotype antibodies will also find use. Where nucleic acids are concerned, one may provide for oligonucleotides bound to the particles which bind to different sites on the compound of interest. Alternatively, one may prepare a strand which has repeats of the same sequence as a reagent which can compete with a nucleic acid compound of interest, so as to cross-link the particles. Also, as indicated previously, one may use combinations of naturally occurring specific binding pairs, such as CD4 and gp120, P-selectin and L-selectin and their correlative homing receptors, CD3 and MHC, integrin adhesion receptors and their adhesive ligands, growth receptors and growth factors, cytokines and their cell surface receptors.

In yet another embodiment of the present invention, the particle surface is not specifically coated with a binding component prior to assay, but rather fibrinogen present in a blood sample brought in contact therewith may naturally adsorb to the particle surface so as to provide a binding component.

If the use of an absorbing dye is desired, the particles are loaded with a dye that absorbs in the infrared. Dyes that find use herein will preferably exhibit the capability of absorbing around 800 nm, will have high absorption coefficients and/or will exhibit broad absorption spectra. Various dyes have been reported as having these properties. See, e.g., Fabian et al., *Chem. Rev.* 92:1197-1226 (1992). These dyes include, for example, bacteriochlorin, bacteriochlorophytin, meropolymethine dyes, benzoannulenes, vinylogous porphyrins, polymethine dyes, cyanines and merocyanines, and the like. The particular dye which is selected is one of convenience, availability, stability, compatibility with the particle, and the like. Specific dyes of interest include dyes of the class of pthalocyanines, napthalocyanines, metaled napthalocyanine dyes, and modified natural bacterochlorines. Examples of specific dyes that find use herein include IR-132, IR-140, 1,1'-Diethyl-4,4'-dicarbocyanine iodide, 1,1'-Diethyl-2,2'-quinotricarbocyanine iodide, Vanadyl 3,10,17,24-tetra-*tert*-butyl-1, 8, 15, 22-tetrakis(dimethylamino)-29*H*, 31*H*-phthalocyanine, IRA800 (from Exciton), ProJet 830NP (from Zeneca), 2,3-Dicyano-4-[4-(dimethylamino)phenylimino]-1,4-naphthoquinone, 9-[4-(Dimethylamino)phenylethynyl]-thioxanthenylium perchlorate, 2-[4-(4-Dimethylaminophenyl)-1,3-butadienyl]-4-phenyl-1-benzothiopyylium perchlorate, 2-

[2-[2-Chloro-3-[2-(1,3-dihydro-1,3,3-trimethyl-2H-indol-2-ylidene)ethylidene]1-cyclohexen-1-yl]ethenyl]-1,3,3-trimethyl-3H-indolium perchlorate, N-[4-[5-(4-dimethylaminophenyl)-3-phenyl-2-penten-4-yn-1-ylidene]-2,5-cyclohexadien-1-ylidene]-N,N-dimethylammonium perchlorate, N,N-diethyl-N-[4-[1,5,5-tris(4-diethylaminophenyl)-2,4-pentadienylidene]-2,5-cyclohexadien-1-ylidene]ammonium perchlorate, 1-Ethyl-4-[5-(1-ethyl-4(1H)-quinolinylidene)-1,3-pentadienyl]quinolinium iodide and 1-Ethyl-4-[3-chloro-5-9]-ethyl-4(1H)-quinolinium iodide. These dyes may be incorporated directly into the particle itself, through polymerization, may be covalently attached to the particle either through direct covalent attachment to the particle surface or through a latex deposited onto the particle surface or by passive adsorption. Alternatively, the dyes may be linked to the bead in combination with the binding component, such that they do not leach from the surface. The dyes that find use herein may optionally be made more hydrophobic, i.e., for incorporation into a latex, by substitution of one or more of the methyl and/or ethyl groups of the dye with alkyl chains that may comprise up to 20 or more carbon atoms, often up to 100 or more carbon atoms, wherein these substitutions will not be expected to significantly adversely affect the infrared absorption profile of the dye.

In another embodiment of the invention, the dye may be a naphthalocyanine having the following formula:



wherein

M is selected from the group consisting of Si, Al, Sn, Ge, V and Ti;

$R_1$ to $R_{12}$ are selected from the group consisting of hydrogen, alkyl, and alkoxy having from 1 to 20 carbon atoms, and

X and Y may be the same or different, wherein one or both may be absent, and are selected from the group consisting of OR, OAr and $OSi(R)_3$, where R has the definition of $R_1$ to $R_{20}$.

Preferably, when M is Al, Y alone should be bound to M and X is absent, in which R is an alkyl or alkoxy group having from 1 to 20 carbon atoms bound directly or through other heteroatoms. X and Y will serve to reduce the stacking of the aromatic ring system while improving the solubility of the dye. $R_1$ to $R_{12}$ may be bound directly or through other heteroatoms and may be present in whole or only in part.

The dyes will absorb light in the range of about 750-900nm, particularly in the range of about 750-850nm. For samples with high levels of red blood cells, the light will be at about 800nm ±10nm, which is the isobestic point for oxyhemoglobin and reduced hemoglobin. The amount of the dye employed with the particles will vary with the extinction coefficient of the dye in the light range of interest, the required sensitivity of the assay, the size of the particles, the mode of binding of the dye to the particles, compatibility of the dye with the particle matrix, and the like. Usually, loading will be in the range of about 1 to 20 weight percent, more usually 5 to 15 weight percent.

As already alluded to, other reagents may be present. Particularly, where a monoepitopic compound is the compound of interest. With a monoepitopic compound, where specific binding pairs are involved for cross-linking, in order to get cross-linking, one will need at least a dimer of such component or a mimetic analog thereof. Usually the reagent will have not more than about 5 of the cross-linking epitopes present. With this polyepitopic reagent, in the absence of the compound of interest, there will be aggregation. Increasing amounts of the compound of interest will reduce the amount and rate of aggregation. Alternatively, one may use multibinding receptors which will crossreact with the binding component and the

compound of interest. The compound of interest will fill the binding sites of the receptors, preventing crosslinking, again reducing the amount and rate of aggregation. In this way, one can detect monoepitopic compounds.

One may assay compounds which activate or inhibit catalysts, whether naturally occurring or synthetic, particularly enzymes which can activate the binding component to cause aggregation, e.g. thrombin and fibrinogen, casein or fibronectin and transamidases, etc.

Other reagents which may be present include substances which may modify the compound of interest, such as activating a particular cellular function, upregulating or downregulating expression of a particular surface membrane protein, competing with the compound of interest for the binding component on the particle, blocking binding by a substance which competes with the compound of interest for binding to the binding component present on the particle, e.g. alleles, isotypes, etc., in order to avoid false positives associated with the competitive substance, and the like. These additional reagents will be selected in accordance with the nature of the compound of interest, the protocol of the assay, and the like.

In each case the amount of the other reagents will be determined empirically. If one is using a polyepitopic reagent for competition with a monoepitopic compound of interest, the reagent will be selected to give the highest sensitivity over the dynamic range of interest. This may vary from less to greater than stoichiometric and may be readily determined. One varies the concentration of the reagent with the lowest anticipated concentration of the compound of interest and the highest anticipated concentration of the compound of interest. One may the choose one or two intermediate points to determine the greatest sensitivity at these intermediate points. By graphing the results, one can determine the concentration of the reagent which will provide the most sensitive result over the dynamic range, a higher response being required at the lower part of the range than at the higher part of the range.

In carrying out the subject method, the sample, which may have been subject to prior preparation, is combined with the necessary reagents with mild agitation. Various conventional procedures for preparation of the sample may be employed. Depending upon the nature of the sample, the sample may be protected from the atmosphere or be in contact with the atmosphere. Protection from the atmosphere

may be achieved by employing sealed containers, where the containers are sealed with a septum, and the sample is introduced by means of a needle through the septum, with the receiving container being evacuated or containing an inert gas. Optionally, a humidity indicator may be employed in the sealed containers so as to provide information as to moisture in the chamber (see, e.g., U.S. Patent No. 4,793,180). Such indicators are also commercially available through Humidial Corp, Colton, CA.

Conveniently, relatively large or small samples may be taken and only small aliquots used in the assays. Thus, the assay volume may be from about 5$\mu$l to 500$\mu$l, usually from about 25$\mu$l to 250$\mu$l, and conveniently from about 25$\mu$l to 150$\mu$l.

The sample is combined with the particles and any other reagents under conditions where the particles are rapidly dispersed throughout the sample. The particles and other reagents may be present as a dry composition or dispersed with a small amount of liquid. Usually the volume of the particles and reagents will be not more than about an equal volume to the sample, preferably less than about 50% of the sample volume, more preferably less than about 25% of the volume sample.

A reading is taken at 0 time or some convenient interval to obtain a 0 value, which is the value in the absence of significant aggregation. Readings may then be taken from time to time. Automated instrumentation can be employed to mix the sample with the particles and any other reagents, heat the assay mixture to the desired temperature, carry out any necessary operations during the assay, monitor the assay mixture to take the first reading, for example, when the sample has reached the desired temperature, take additional readings, as appropriate, and then calculate the assay result for the sample, with any other descriptive information associated with the sample.

The concentration of particles in the medium will be optimized in accordance with the nature of the compound of interest, the dynamic range of the compound of interest, the nature of the sample medium, and the like. The amount of the particles may be determined empirically. Generally, the aggregation media absorption coefficient should be at least twice the absorption coefficient of the sample, preferably at least three times, more preferably at least about four times, and may be ten times or more. In the absence of any substantial background in the infrared, there is no effective ratio.

The time for mixing may be varied widely, usually being at least about 1 sec. and not more than about 5 min., usually not more than about 2 min., and preferably for about 5 sec. to 1 min. The particular manner of agitation is not critical to this invention, so long as it provides for thorough mixing, without preventing the formation of aggregates. If desired, mild agitation may be maintained during the course of the assay, again insuring that there is homogenous distribution of the particles and any other particulate matter, while insuring that aggregation is not impeded.

The temperature for the assay may be varied widely, depending upon the nature of the compound of interest. Conveniently, ambient temperatures may be employed, although elevated temperatures which can be controlled and maintained are preferred. Where nucleic acids are involved, the temperature may be elevated, so as to enhance the degree of stringency of hybridization. Thus, the temperature may vary from about 15-90°C, where with other than nucleic acids, the temperature will generally vary from about 25-40°C. Usually, with nucleic acids the temperature will generally be in the range from about 20-90°C, more usually in the range of about 30-85°C.

With nucleic acids, stringencies may be achieved by using salts, organic solvents, and the like. However, with other than nucleic acids, normally the only addition will be a buffer, if at all, where the buffer will range from about 5-10 in pH, more usually from about 6-9, and at a concentration of from about 10-500mM, more usually from about 25-250mM.

The time for the assay will vary depending upon the manner in which the measurement is taken. Where zero time is carefully controlled, one may take one or two measurements at different time intervals to determine the absolute infrared transmission at the time intervals or determine the rate of formation of the aggregation. Alternatively, one may take a plurality of measurements over the time course of the assay and analyze the slope beginning at a fixed time from the time of mixing. The data may be analyzed by any convenient means, particularly using an algorithm which can manipulate the data in relation to calibrators and/or controls. The total time of the readings from the zero time (time of mixing), may range from

about 10 sec. to 5 min., more usually about 30 sec. to 5 min., and preferably about 30 sec. to 2 min.

Usually, the result will be compared to a calibrator, which may be performed concomitantly or have been performed previously or may be provided as a standard curve. The calibrators will vary depending upon the nature of the compound of interest. Samples having known amounts of the compound of interest may be prepared and performed in the assay and the results charted so as to be able to translate the measurement obtained with the sample to the standard. In some instances controls will be used, where the base value may vary depending on the source of the sample. The particular control will be associated with the sample and the compound of interest.

The subject invention finds particular application in conjunction with the determination of platelets and platelet function. Platelet adhesive function is an extreme test of the subject methodology in the sensitivity to various factors of platelets. First, platelets can be activated to varying degrees by the physical manipulation of blood and by the release of factors elicited when blood vessels are damaged on venipuncture. Second, is the effect of the time between drawing the blood and testing: for techniques requiring plasma this time is necessarily longer and therefore less desirable. In addition, the mechanical action needed to separate plasma from red cells can activate the platelets to varying degrees and also result in variable cell recovery. When measuring the effectiveness of inhibitors of platelet adhesive function, there is the issue of the relatively fast off-rate. The rapid off-rate of an inhibitor means that its effect will be underestimated if the sample is diluted prior to assay, and in some cases, even if the dilution occurs during the assay. Also, since platelet aggregation, fibrinogen binding and, in some cases, inhibitor binding are calcium dependent, the choice of anticoagulant may be important in accurately determining platelet function levels. Variability in absorption, metabolism, etc., of the anti-IIb/IIIa drugs may lead to large differences in pharmacokinetics. The subject methodology allows for a rapid determination of the effective level of inhibition of platelet adhesive function and/or the ability of platelets to aggregate. This information, permits accurate decision making on timing and frequency of dosing with anti-platelet drugs aimed at inhibiting clot formation.

Where platelet aggregation is to be measured, because of interest in the platelet status of an individual, which may be the natural status or the status resulting from administration of a drug, the sample will be in effect whole blood, which has been subjected to less than about 50%, preferably less than about 20% dilution.

The whole blood is drawn desirably in the substantial absence of air. Conveniently, a Vacutainer is employed for capturing and holding the blood sample. The Vacutainer desirably includes a small volume of a solution of sodium citrate (or other anticoagulant) generally in the range of about 3-5% sodium citrate having a volume in the range of about 0.05-0.5ml. The blood sample should be obtained from an extremity free of peripheral venous infusions. Conveniently, the needle should be at least about 21 gauge.

The first tube which is withdrawn is discarded, the second tube or subsequent tubes being used. Mild agitation, simply gently inverting the Vacutainer is employed to insure the mixture of the anticoagulant with the sample. The sample in each container may range from about 1-10ml, more usually from about 1-8ml, conveniently from about 1-5ml. The sample should not be stored for an unduly long period, generally storage before the assay should not exceed 1 hour.

A small portion of the sample may then be transferred to a cuvette for measurement. Generally, the volume may range from about 25-500$\mu$l more usually from about 75-250$\mu$l. Conveniently the cuvette contains the particles which have been coated with fibrinogen or other binding compound. The platelets may be activated by the addition of various agents, which serve to activate the platelets. Illustrative agents include iso-TRAP (See U.S. Patent No. 5,455,228), TRAP, ADP, collagen, thrombin, ristocetin, arachidonic acid, or any combination thereof. Any convenient activator may be employed. Iso-TRAP is employed at a concentration in the range of about 1 to 5, preferably about 2 $\mu$mol/L. ADP may be employed in the range of about 20 $\mu$M as a GPIIb/IIIa antagonist or lower concentrations for monitoring aspirin, ticlopidine and/or clopridogrel. The activating agent may be incorporated with the bead reagent to which the blood sample is added. The beads and other reagents may be dry, so as to not dilute the sample, although in some instances a small amount of liquid may be present, desirably less than about 25% of the volume of the sample.

The particles are conveniently polystyrene particles of a size in the range of about 2 to 8 microns, which have been coated with fibrinogen by passive adsorption or by covalent linkage in accordance with conventional ways and as described above. Generally, the weight of fibrinogen to the weight of particles will be in the range of about 1:1000 to1:10.

The amount of beads should provide a ratio between the agglutination media absorption coefficient and whole blood absorption coefficient of greater than about 4:1 at 800nm, generally not more than about 10:1 at 800nm. The optimal absorption ratio may be achieved by configuring both the light-absorbing characteristics of the agglutination media and the concentration of the agglutination media in the assay sample.

The mixture of anticoagulated whole blood, particles and activating agent is gently agitated to insure homogeneity and the mild agitation is continued so as to maintain homogeneity without impeding aggregation formation. The temperature for the medium will be maintained at a constant temperature. After a short time, generally under 30 sec., usually under about 10 sec., readings are begun by illuminating the sample with light at about 800nm. The total time for the readings will generally be under about 5 min, usually under 3 min, where, when one is determining the rate of change to determine the change in slope with time, the number of data points per second may range from about 0.01 to 100, more usually from about 1 to 50. Thus one may take readings at constant intervals of from about 0.01 sec to about 1.5 sec, usually from about 0.02 sec to 1 sec. Otherwise, data points may be taken as convenient, there being at least one data point, more usually at least two data points, frequently not fewer than 1 per minute. The change in transmissibility with time is determined by any convenient technique, conveniently employing a conventional spectrophotometric detector for the infrared.

As a control, blood containing a coagulation inhibitor is treated with a reagent, conveniently an antibody or fragment thereof which completely neutralizes the inhibitor. It is found that the baseline for platelet activity can vary widely with time for a patient and between patients, so that by neutralizing the inhibitor one can get the baseline value for platelet activity for the particular sample. This may then be used for comparison with the results obtained with the sample to determine the platelet

activity in the presence of the inhibitor. Illustrative compounds which find use as inhibitors include Searle compounds 54701B and 57101A, which are potent IIb/IIIa function blocking drugs. Antisera or monoclonal antibodies or binding fragments thereof can be used to block the action of the inhibitor and the resulting uninhibited sample used for the control. The control would be used in the same way as the sample and could be run concurrently so that the same conditions are employed for the control as are employed for the sample.

The amount of inhibitor neutralizing agent which is employed will provide for complete neutralization of the inhibitor and excesses may be used, usually not more than about five-fold excess of the maximum concentration of the inhibitor, as anticipated from the dose given to the patient, without significant dilution of the sample, usually less than about 50% dilution, usually less than about 25% dilution. Where antiserum or fragment thereof is used, high affinity titers should be used, desirably 50% maximum binding should be at a titer ranging from at least about 1:10,000 and maybe 1:100,000 or more, preferably at least about 1:25,000. By employing this technique, one may establish a baseline rate, or any other IIb/IIIa functional test baseline parameter.

The subject particles without fibrinogen, serving as surrogate platelet control or calibrator, can be combined with thrombin and/or Gly-Pro-Arg-Pro (GPRP; a peptide inhibitor of fibrin polymerization) in an appropriate buffered medium. These reagents may then be combined with the particles coated with fibrinogen in the same manner as the sample. If desired, the buffered medium may be augmented with blood constituents, such as red blood cells, serum albumin, immunoglobulins, or other significant constituent of blood, which does not participate in the aggregation of the particles. A convenient buffer medium is a HEPES-sodium chloride buffer comprising from 1-5mg/ml protein e.g. BSA.

In other embodiments, additional controls or calibrators may be employed. For example, while a baseline (100% maximum assay rate) level of control may be provided by combining fibrinogen-coated particles with about 0.5 to 10 NIH units/ml, preferably about 0.6 NIH units/ml, of human thrombin in an appropriate buffered medium such as that described above, an approximately 50% level control (about 50% of the maximum assay rate) is provided wherein fibrinogen-coated particles are

combined with about 0.5 to 10 NIH units/ml, preferably about 0.6 NIH units/ml, of human thrombin in an appropriate buffered medium such as that described above and from about 15 to about 30, preferably about 23 μg/ml of the GPRP oligopeptide, a peptide inhibitor of fibrin polymerization. Preferably, the 100% level control contains about 0.6 NIH units/ml thrombin in 10 mM HEPES buffered saline, 2 mg/ml BSA, 0.2% trehalose, 0.4% Tween 20, 0.9% of 0.5 μm polystyrene latex.

Additional controls may employ the murine monoclonal antibody 4A5 (G. Matsueda, Princeton University), which was generated against a peptide immunogen to mimic the intermolecular crosslinking site in the γ chain of human fibrin and reacts with both fibrinogen and synthetic fibrinogen-based oligopeptides. Specifically, when 4A5 is coated onto the surface of 2-3 μm polystyrene latex, the complex is capable of agglutination of fibrinogen coated latex particles in a manner wherein a direct correlation exists between the amount of 4A5 coated latex added and the rate of agglutination.

Additional controls may also employ isolated platelet plasma membranes that are coated onto the surface of polystyrene latex particles. Such membrane-coated particles are capable of agglutinating fibrinogen-coated particles in a manner wherein a direct correlation exists between the amount of membrane-coated particles added and the rate of agglutination. If desired, GIIb/IIIa inhibitors at various concentrations may also be employed.

The above controls may be performed independently from the subject assays or may performed in conjunction with the subject assays. When the control is performed in conjunction with the subject assay, it may be performed in an apparatus that is separate and distinct from that being employed for the subject assay or may be performed in the same apparatus being used for the subject assay provided that that apparatus comprises at least two distinct chambers that can be employed for the test and control assays.

If one wishes, this technique as modified may also be used in evaluating the activity of various proteins in the blood, which are associated with thrombin activation and aggregation. These proteins include FV, FVIIIc, FIX, and other factors previously described. Thus, by adding a blood sample to a prepared mixture, which may be dry and require reconstitution or a concentrated solution, which contains the

necessary blood factors for coagulation, except for the factor to be measured, and the fibrinogen coated particles, a change in the rate of aggregation will be related to the activity of the factor of interest in the sample. The result may then be related to calibrators having known amounts of the factor of interest.

After the sample has been combined with the reagents, desirably it will be heated to a temperature above room temperature, but below interference with the assay, so as to insure that the temperature can be controlled without adversely affecting the assay result. Desirably, the temperature should be at least 25°C, preferably in the range of 30-40°C, more preferably about 37°C. While not essential, it is preferable that the sample be mildly agitated during the incubation and measurement of the aggregation. For agitation, metal beads may be moved up and down, magnetic beads oscillated at a slow rate or other means employed for mild agitation.

The sample volume can be quite small, usually being not less than about 10$\mu$l, more usually not less than about 25$\mu$l, and desirably not more than about 1ml, preferably not more than about 500$\mu$l, more preferably not more than about 250$\mu$l.

For convenience, kits can be provided comprising some or all of the reagents which find use in the subject invention. The kit will have the particles for use with the component of interest. In addition, neutralizing immunoglobulins may be provided for removing inhibitor in a sample to serve as a control. Calibrators may be provided providing particles with the appropriate binding component mixed with any other reagents associated with the assay and, if desired, a source of the component of interest, either in measured amounts or in bulk. For platelet aggregation, a combination of thrombin and/or GPRP and uncoated particles may be supplied. Also, of convenience, would be Vacutainers comprising 0.1-1ml of 1-5M anticoagulant, e.g. sodium citrate, a thrombin inhibitor. Of particular interest for the kit is a container containing one or more of the appropriate reagents in order to reduce the manipulative steps for the assay. For example, a container, such as a cuvette, may be provided containing the particles and, as appropriate, other reagents for the assay

Another embodiment of the present invention is directed to assays and kits useful therefor that are capable of sensitively detecting and quantitatively measuring the presence of molecules of interest which exist at low concentrations in a sample,

such as for example, cardiac troponin I and P-selectin. In these assays, one may attach to the surface of a first particle using standard methodology a receptor molecule, preferably an antibody or antigen binding fragment thereof, which is directed against a molecule of interest that is present in the sample at low concentrations, where the molecule of interest is preferably a protein or peptide. Binding of the molecule of interest to the surface of the receptor-coated first particle does not significantly affect the ability of the first particle to absorb or emit in the infrared range. However, a second particle, preferably a particle that has little or no inherent infrared absorption and/or emission capabilities, such as a white latex particle, and which is coated with a receptor molecule, preferably an antibody or binding fragment thereof, that is directed against a different site on the molecule of interest, is added. The second particle is then available for binding to the molecule of interest that is already bound to or becomes bound to the first particle, thereby altering the infrared absorption and/or emission characteristics of the first particle, wherein this alteration in infrared absorption and/or emission may be detected and quantitated over time. The sample may be combined with the first particle prior to, at the same time as or after the second particle is added to the sample, wherein the order of combination will not be critical to the invention. Particles that find use herein are as described above.

Yet another embodiment of the present invention is directed to assays and kits useful therefor for detecting and quantitatively measuring the total number of platelet receptors in a sample of interest as a measure of platelet count. Specifically, particles are coated as described above with receptor molecules, preferably antibodies or antibody fragments, directed against a platelet-associated protein such as, for example, GPIb, GPIIb/IIIa, and the like, and combined with a sample of interest. Alterations in the ability of the system to absorb in the infrared range over time will provide information as to the total number of platelet receptors in the sample which may then be correlated with platelet count.

The following examples are offered by way of illustration and not by way of limitation.

## EXPERIMENTAL

The beads used in the subsequent experiments were prepared as follows:

### Preparation of human fibrinogen-coated latex beads

To 8.369 mL of DI water in a 15 mL polypropylene conical tube is added 0.208 mL of 0.96 M sodium phosphate at pH 7.2 with 0.02% sodium azide. Four hundred and twenty-three microliters of human fibrinogen ( from Enzyme Research Laboratories, South Bend, Indiana; cat # Fib 3 ) at 7.8 mg/mL is then added and gently mixed. Finally, 1 mL of 5.5 micron latex beads ( from Bangs Laboratories; polystyrene with 5.5 % DVB and 5 % methacrylic acid ) at 10 % is added and the mixture is incubated at room temperature on a rocker for 2 hours. It is then centrifuged at 1540 g for 5 minutes on a swinging bucket rotor. The supernatant is decanted and 10 mL of Buffer C ( 10 mM HEPES with 1 mg/mL BSA and 0.02% sodium azide at pH 7.5 ) is added to resuspend the beads. The mixture is centrifuged and the above procedure carried out again. After the last centrifugation, the supernatant is decanted and 6.67 mL of Buffer A is added to resuspend the beads. The bead concentration is usually $1.38 \times 10^8$ beads per mL. A modification of the bicinchonic acid (BCA) assay (Pierce, Rockford, IL) is used to determine the amount of fibrinogen coated on beads. The preparation of human fibrinogen-coated blue latex beads is done in an identical fashion, except that 6 micron blue latex beads (from PolySciences, polystyrene with carboxylate groups ) are used.

### Preparation of IR-140 Dye Solution

Forty-five milligrams of IR-140 is dissolved in 9 mL of methylene chloride in a glass tube. It is then mixed with 38 mL of 2-propanol, followed by 53 mL of Buffer B ( 20 mM sodium phosphate with 0.02% sodium azide at pH 7.5 ) in a glass jar. The mixture is mixed vigorously with a ColePalmer stirrer Model 50002-30 for 15 minutes to make a homogeneous dye solution.

### Preparation of IR-140-dyed human fibrinogen-coated latex beads

To a pellet of human fibrinogen-coated latex beads ( $1 \times 10^9$ beads ) is added 10 mL of the above IR140 dye solution, followed by vortexing. The mixture is incubated at RT on rocker for 5 minutes and then transferred to a 50 mL polypropylene conical

tube and QS'd to 50 mL with Buffer A. After 5 min of spin at 1540 g and removal of supernatant, the above dye-loading process is carried out a second time. After centrifugation and removal of supernatant, 9.75 mL of Buffer B is added and vortexed, followed by addition of 0.25 mL of 7.8 mg/mL human fibrinogen and gentle mixing. The mixture is then sonicated for 45 seconds. Purification (use of Buffer C and centrifugation) is carried out the same way as in the Section on Preparation of human fibrinogen-coated latex beads.

In the following experiment, the subject methodology was employed in conjunction with the Searle compound 54701B, a compound having platelet aggregation inhibition capability. The method employed was as follows.

**General Approach**

Citrated blood is added to a cartridge containing proprietary microparticles and thrombin receptor activating peptide (iso-TRAP). Microagglutination is optically monitored as the mixture is mechanically mixed. Platelet activity is determined by the rate of change of the optical density of the solution. The results of this assay are compared to results from optical platelet aggregometry performed on platelet rich plasma (PRP).

**Methods:**

**Specimen Collection and Preparation:**

Human blood (40.5 ml) was collected from six non-smoking aspirin free volunteers into 5.0 ml citrated (3.8%) tubes using a Vacutainer system (Becton Dickinson, Franklin Lakes, NJ) with a 21 gauge needle. The first tube was discarded and the remainder pooled into a polypropylene container and maintained at a room temperature. Aliquots of 5 ml of pooled blood were transferred to 12x75 mm polyproplyene tubes and 250 µl of blood withdrawn and discarded. Searle compound 54701B was diluted with 10 mM HEPES, 150 mM NaCl, pH 7.4 and 50 µl added to each tube resulting in final concentrations of 10, 25, 35, 50 and 75 nM. A minimal aggregation sample at 1000 nM was prepared for all samples. Control samples to assess maximum aggregation were prepared simultaneously with 250 µl of the HEPES/Saline buffer added in place of the antagonist.

Aliquots of whole blood with inhibitor (2.0 ml) were removed and placed into separate polyproplyene tubes for performance of the Rapid Platelet Function Assay (RPFA). The remainder of the blood in the tubes was centrifuged at 110 x G for 12 minutes and the platelet-rich plasma (PRP) collected into separate polypropylene tubes. Platelet poor plasma (PPP) was prepared by centrifuging a separate aliquot of blood at 1540 x G for 15 minutes. Assays for platelet function were begun within 1 - hour of blood collection.

In a similar study depicted in Figure 4, blood was collected and treated as above, except that six donors were drawn on three consecutive days. Hence, the results are reported as an average of the data obtained on those three days.

**Platelet Aggregometry:**

PRP (400 $\mu$l) was pipetted into a siliconized cuvette containing a Teflon coated stir bar. The cuvette was placed into a Chrono-Log model 490D optical platelet aggregometer and a baseline tracing was established for 30 seconds. ADP (44 $\mu$l) at 200 $\mu$M was added for a final ADP concentration of 20 $\mu$M. Aggregation was monitored for two minutes and the maximal aggregation recorded.

**Rapid Platelet Function Assay:**

A 160 $\mu$l aliquot of the whole blood with inhibitor or buffer prepared above for the RPFA was added to a plastic cuvette containing lyophilized iso-TRAP and microparticles. The mechanical mixing cycle was activated for 70 seconds with optical reading sampled at a rate of 16 per second. Microagglutination was determined by the rate of change of the optical density of the solution over a fixed interval.

The RPFA monitor uses an IR diode with peak wavelength at 805 nm, a spectral bandwidth of 50 nm, and a radiant output power of 15 mW. The transmitted signal is detected by a high gain wide-bandwith optical detector amplifier hybrid with a responsivity at 805 nm of 0.6 A/W. Upon addition of the 160 µL whole blood sample to the assay cartridge, a motor driven mixer is run for a duration of 70 seconds at 240 cycles/min. During this mixing period, the detector signal output is sampled at

a rate of 16 Hz. Upon completion of mixing, the raw time domain data is processed to provide a measure of platelet inhibition.

**Results**

As can be seen in Figure 1, the rate of agglutination of the 6 micron fibrinogen-coated blue latex beads as monitored in a system employing a LED light source at around 650 nm showed almost a two fold increase upon total oxygenation of the dark venous whole blood, whereas that of the 5.5 micron IR-140-dyed fibrinogen-coated latex beads as monitored in a system employing a LED light source at around 817 nm stayed constant.

All publications and patent applications cited in this specification are herein incorporated by reference as if each individual publication or patent application were specifically and individually indicated to be incorporated by reference.

Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity of understanding, it will be readily apparent to those of ordinary skill in the art in light of the teachings of this invention that certain changes and modifications may be made thereto without departing from the spirit or scope of the appended claims.

WHAT IS CLAIMED IS:

1. A method for determining the character of a sample, employing an aggregating system comprising particles to which are bound a binding component, which particles absorb light in the infrared, and any additional reagents necessary for the aggregation of said particles, said method comprising:

combining a sample with said aggregating system to form an assay mixture;

irradiating said assay mixture with light in the infrared region; and

determining the transmission of infrared light from said assay mixture;

wherein the level of transmission is related to the character of said sample.

2. A method according to Claim 1, wherein said sample is whole blood and said assay mixture has less than about 5-fold dilution of said blood sample.

3. A method according to Claim 2, wherein said whole blood comprises an anticoagulant that does not interfere with an intrinsic activity of a component of said sample.

4. A method according to Claim 2, wherein the infrared light is at about 800nm.

5. A method according to Claim 1, wherein said step of irradiating is conducted at a wavelength which equals an isobestic point of two components of said assay mixture.

6. A method according to Claim 1, wherein said particles are of a diameter in the range of 0.1 to 50$\mu$.

7. A method according to Claim 6, wherein said particles are coated with a protein or a peptide comprising the amino acid sequence RGD or KGD.

8. A method according to Claim 7, wherein said protein is fibrinogen or von Willebrands factor.

9. A method according to Claim 1, wherein said particles are carbon particles.

10. A method according to Claim 1, wherein said particles comprise at least one infrared-absorbing dye.

11. A method for determining platelet adhesive activity in a sample, employing an aggregating system comprising particles which absorb light in the infrared and to which fibrinogen is bound, and any additional reagents, said method comprising:

combining a blood sample comprising platelets with said aggregating system to form an assay mixture;

irradiating said assay mixture with light in the infrared region; and

determining the transmission of infrared light from said assay mixture;

wherein the level of transmission is related to the activity of said platelets in said sample.

12. A method according to Claim 11, wherein said aggregating system comprises a platelet activating compound.

13. A method according to Claim 11, comprising the additional steps for a control value of:

combining (1) a composition comprising thrombin, (2) uncoated particles, and (3) fibrinogen coated particles which absorb in the infrared, where the concentration of coated particles is comparable to the concentration in said assay mixture, whereby aggregation of said coated particles occurs;

irradiating said control mixture with light in the infrared region; and

determining the transmission of infrared light from said assay mixture;

wherein the level of transmission is indicative of the base value without the participation of platelets.

14. The method according to Claim 13, wherein said composition comprising thrombin comprises an oligopeptide having the amino acid sequence Gly-Pro-Arg-Pro.

15. A method according to Claim 11, comprising the additional steps for a control value of:

combining (1) particles coated with platelet plasma membranes or an anti-fibrinogen antibody, (2) uncoated particles, and (3) fibrinogen-coated particles which absorb in the infrared, where the concentration of coated particles is comparable to the concentration in said assay mixture, whereby aggregation of said coated particles occurs;

irradiating said control mixture with light in the infrared region; and

determining the transmission of infrared light from said assay mixture;

wherein the level of transmission is indicative of the base value without the participation of platelets.

16. The method according to Claim 15, wherein said anti-fibrinogen antibody is 4A5.

17. A method for determining the presence of a ligand of interest, employing an aggregating system comprising particles to which are bound a binding component, which particles absorb light in the infrared, and any additional reagents necessary for the aggregation of said particles, wherein said ligand modulates the aggregation of said particles resulting from said binding component, said method comprising:

combining a sample with said aggregating system to form an assay mixture;

irradiating said assay mixture with light in the infrared region; and

determining the transmission of infrared light from said assay mixture;

wherein the level of transmission is related to the presence of said ligand of interest in said sample.

18. A method according to Claim 17, wherein said ligand is a molecule of less than 5kD.

19. A method according to Claim 17, wherein said ligand is a molecule of greater than 10kD.

20. A method according to Claim 17, wherein said particles are of a size in the range of 0.1 to 50$\mu$.

21. A method according to Claim 20, wherein aid particles are of a size in the range of 2 to 8$\mu$.

22. A method according to Claim 17, wherein said sample is whole blood diluted by less than 5 fold and said infrared light is 800±10nm.

23. A method for determining the presence of a catalyst inhibitor, employing an aggregating system comprising particles, which absorb light in the infrared, to which are bound a binding component and any additional reagents necessary for the aggregation of said particles as a result of the catalytic action on a substrate of said catalyst inhibited by said catalyst inhibitor, wherein said substrate or the catalytic product of said substrate in conjunction with said binding component modulates the aggregation of said particles, said method comprising:

combining a sample comprising said catalyst with said aggregating system to form an assay mixture;

irradiating said assay mixture with light in the infrared region; and

determining the transmission of infrared light from said assay mixture;

wherein the level of transmission is related to the presence of catalyst inhibitor in said sample.

24. A kit for use in a method according to Claim 1, said kit comprising:

particles of a size in the range of 0.1 to 50$\mu$, which absorb light in the infrared and to which are bound a binding component; and at least one additional constituent which is:

at least one antibody to a GPIIb/IIIa inhibitor;

a platelet activator;

a Vacutainer comprising an anticoagulant in an amount to inhibit coagulation;

a mixture of thrombin and particles of a size in the range of 0.1 to 50$\mu$, which absorb light in the infrared; and/or

an assay mixture holder with a mixing entity.

25. A kit according to Claim 24, wherein said binding component is fibrinogen or a peptide comprising the amino acid sequence RGD or KGD.

26. A kit according to Claim 24, wherein said binding component is fibrinogen.

27. A kit according to according to Claim 24, wherein said particles to which are bound a binding component are carbon particles.

28. A kit according to Claim 24, wherein said platelet activator is selected from the group consisting of TRAP, iso-TRAP, ADP, collagen, arachidonic acid, and ristocetin.

29. A kit according to Claim 24, wherein said anticoagulant is citrate.

30. A composition of matter comprising particles of a size in the range of 0.1 to 50$\mu$ which absorb light in the infrared and to which are bound a binding component.

31. A composition of matter according to Claim 30, wherein said size is in the range of 2 to 8$\mu$.

32. A composition of matter according to Claim 30, wherein said binding component is fibrinogen or a peptide that comprises the amino acid sequence RGD or KGD.

33. A composition according to Claim 30, wherein said absorbed light is 800nm±10nm.

34. A composition of matter according to Claim 30, wherein said particles are carbon particles.

35. A composition of matter according to Claim 30, wherein said particles comprise a dye that absorbs in the infrared range.

36. A composition comprising polymeric particles of a size in the range of 0.1 to 50$\mu$ in combination with thrombin.

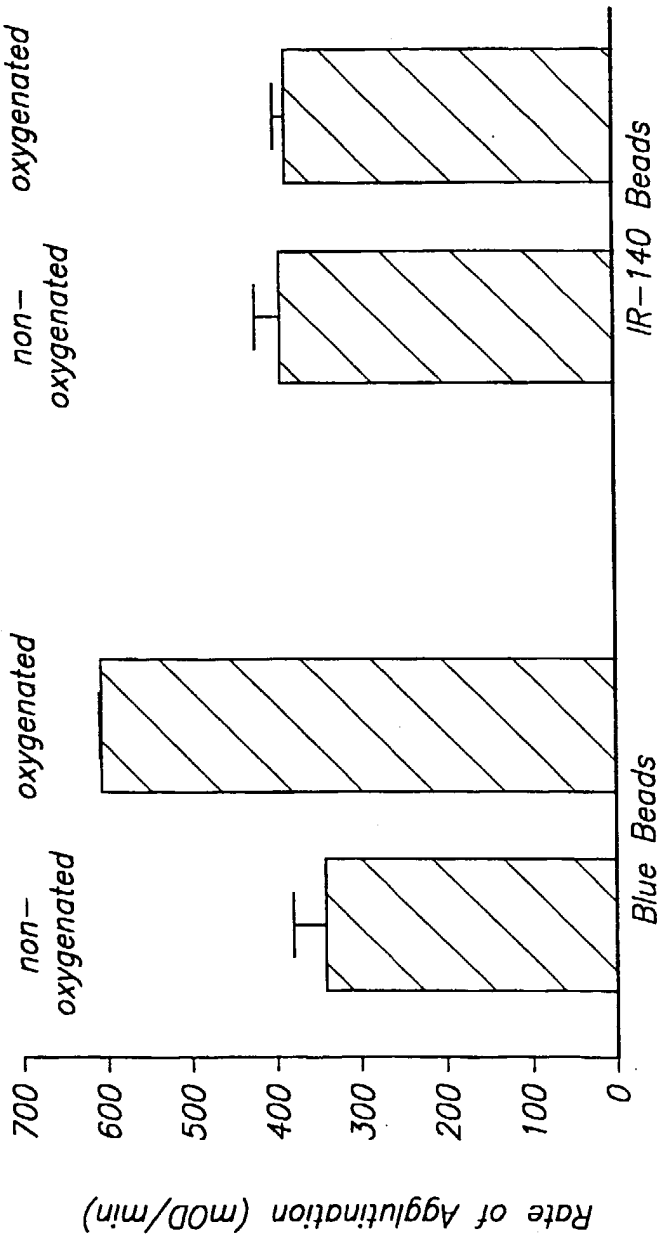

Rate of Agglutination (mOD/min)
700
600
500
400
300
200
100
0
non-oxygenated
oxygenated
non-oxygenated
oxygenated
Blue Beads
IR-140 Beads

Figure 1

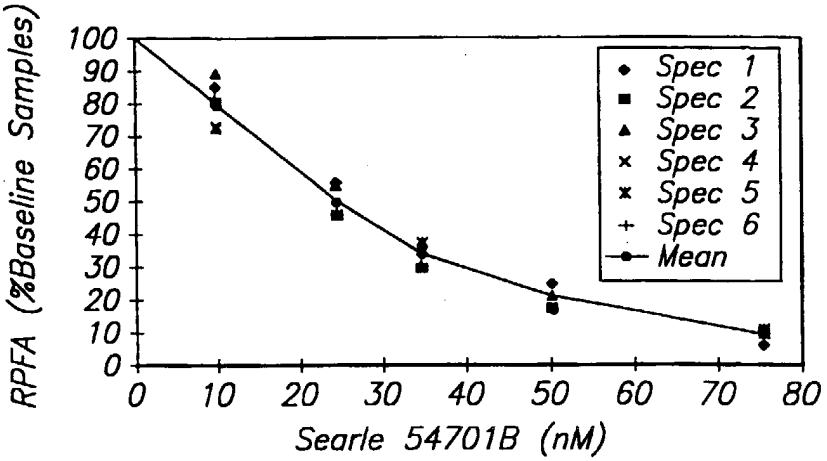



**Figure 2**

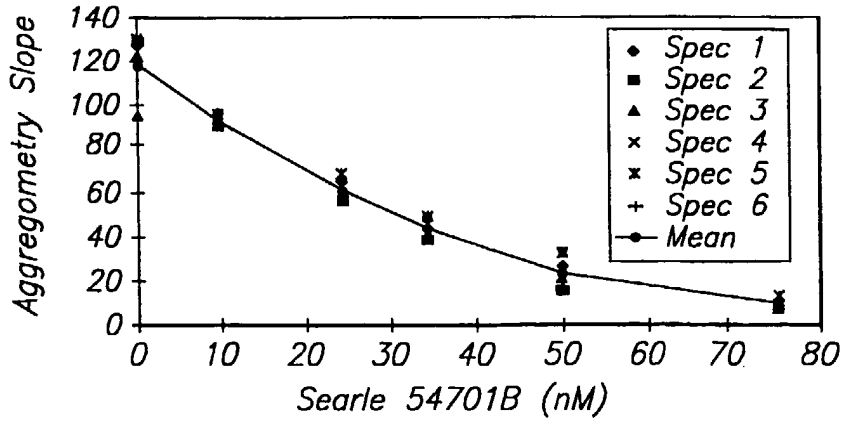



**Figure 3**

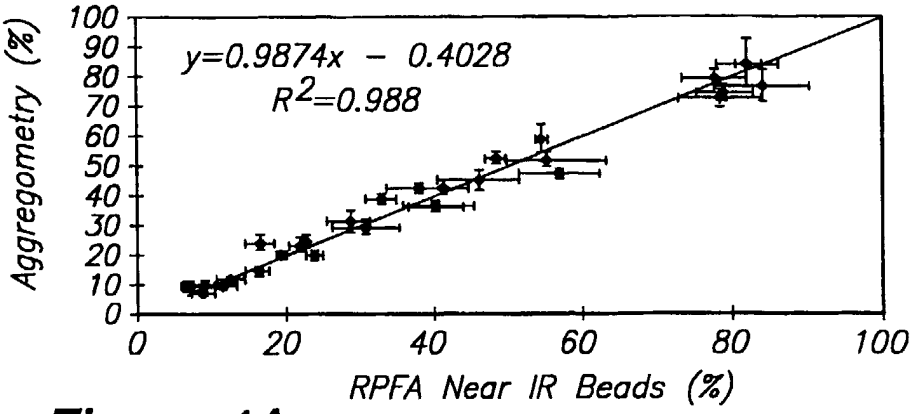



Figure 4A

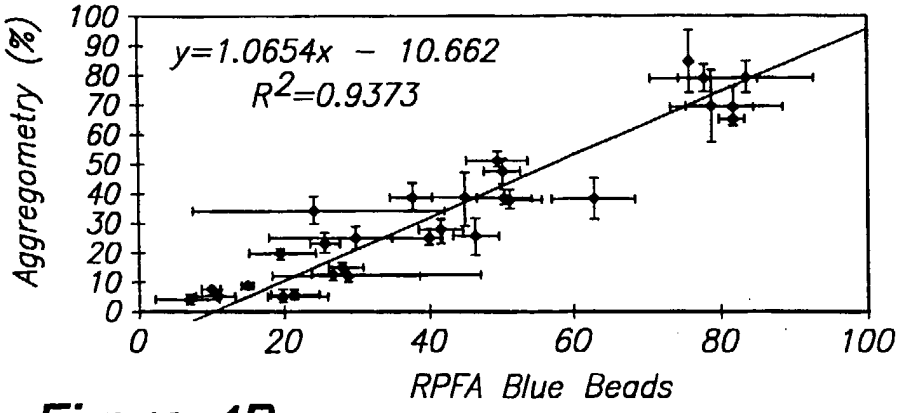



Figure 4B

| SAMPLE | ANTIBODY | % BASELINE | SD | N |
|---|---|---|---|---|
| HBS | | 100.000 | 16.40337 | 6 |
| 2201 | | 102.3643 | 15.42936 | 6 |
| 2237 | | 103.9405 | 18.43019 | 6 |
| IgG | | 100.5838 | 20.47064 | 6 |
| 500 nM SC 54701B | | 0.622592 | 1.174004 | 6 |
| 500 nM SC 54701B | 2201 | 109.4279 | 15.28864 | 6 |
| 500 nM SC 54701B | IgG | 2.340047 | 2.962593 | 6 |
| 500 nM SC 57101 | | 4.670169 | 3.770276 | 6 |
| 500 nM SC 57101 | 2237 | 112.5511 | 19.57767 | 6 |
| 500 nM SC 57101 | IgG | 2.772913 | 2.440345 | 6 |

LEGEND: HBS – Hepes Buffered saline
2201 – Rabbit IgG, anti–SC 54701B
2237 – Rabbit IgG, anti–SC 57101
IgG – Non–specific Rabbit IgG

**Figure 5**

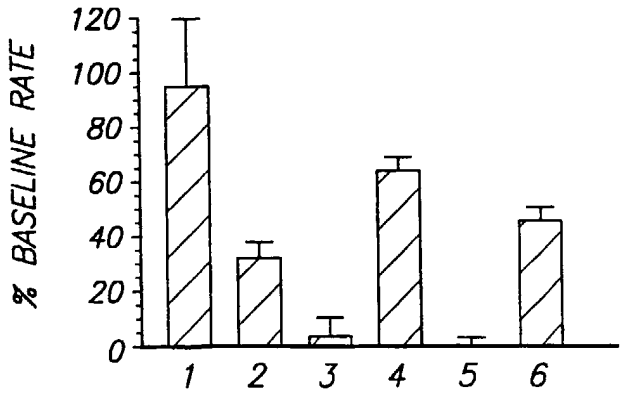



**Figure 6**

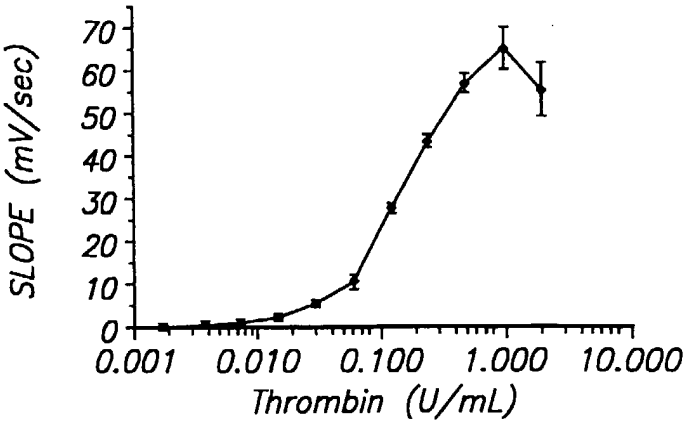



Figure 7

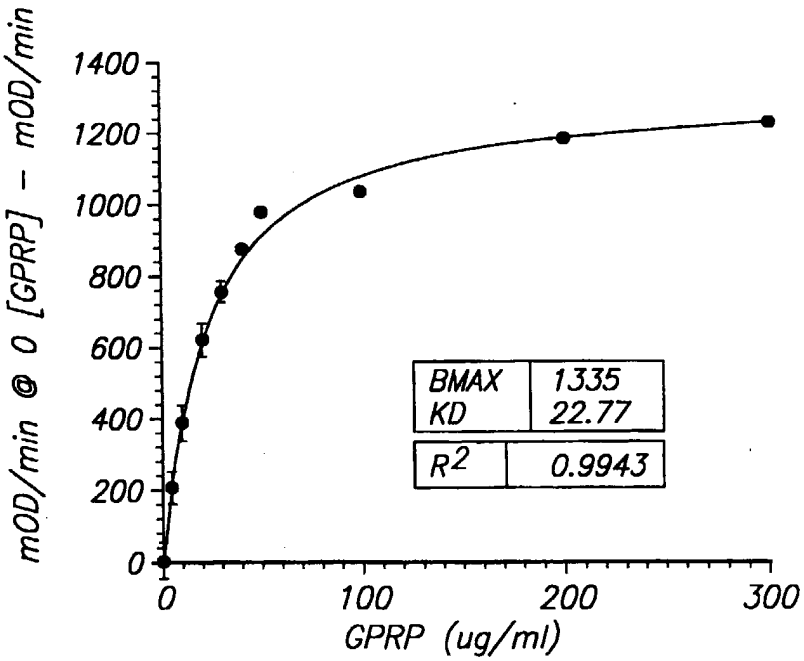



Figure 8

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/06044

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :G01N 33/544, 33/546, 33/551, 33/567, 33/86; C12Q 1/56
US CL :435/7.21, 7.8, 13; 436/518, 524, 534, 69
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 435/7.21, 7.8, 13, 975; 436/503, 518, 524, 528, 534, 10, 69

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS, DIALOG

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X<br>---<br>Y | US 4,224,304 A (SAWAI et al.) 23 September 1980, see entire document. | 1-8, 17-20, 22, 24-26, 28-30, 32-33<br>---<br>1-36 |
| X<br>---<br>Y | US 5,004,923 A (HILLMAN et al.) 02 April 1991, see entire document. | 1-8, 17-21, 23-24, 29-31, 33<br>---<br>1-36 |
| X<br>---<br>Y | US 5,427,913 A (SHAW et al.) 27 June 1995, see entire document. | 24-26, 28-33<br>---<br>1-36 |

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

| | | | |
|---|---|---|---|
| * | Special categories of cited documents: | "T" | later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention |
| "A" | document defining the general state of the art which is not considered to be of particular relevance | "X" | document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone |
| "E" | earlier document published on or after the international filing date | "Y" | document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art |
| "L" | document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) | "&" | document member of the same patent family |
| "O" | document referring to an oral disclosure, use, exhibition or other means | | |
| "P" | document published prior to the international filing date but later than the priority date claimed | | |

| | |
|---|---|
| Date of the actual completion of the international search<br>28 MAY 1998 | Date of mailing of the international search report<br>22 / 06 /1998 |
| Name and mailing address of the ISA/US<br>Commissioner of Patents and Trademarks<br>Box PCT<br>Washington, D.C. 20231<br>Facsimile No. (703) 305-3230 | Authorized officer<br>JAMES L. GRUN, PH.D.<br>Telephone No. (703) 308-0196 |

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/06044

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X<br>-----<br>Y | COLLER, B.S. Interaction of Normal, Thrombasthenic, and Bernard-Soulier Platelets With Immobilized Fibrinogen: Defective Platelet-Fibrinogen Interaction in Thrombasthenia. Blood. February 1980, Vol. 55, No. 2, pages 169-178, see entire document. | 24-26, 28-33<br>-------<br>1-36 |
| X | US 5,252,459 A (TARCHA et al.) 12 October 1993, especially columns 2-3 and 9-12. | 30-31, 33 |
| X | US 5,110,727 A (OBERHARDT) 05 May 1992, especially columns 7-8, 12, and 18-24. | 36 |
| Y | US 5,455,228 A (COLLER et al.) 03 October 1995, see entire document. | 1-36 |
| Y | COLLER et al. A Murine Monoclonal Antibody That Completely Blocks the Binding of Fibrinogen to Platelets Produces a Thrombasthenic-like State in Normal Platelets and Binds to Glycoproteins IIb and/or IIIa. Journal of Clinical Investigation. July 1983, Vol. 72, pages 325-338, especially page 327, column 2. | 1-36 |
| Y | US 5,246,832 A (MICHELSON et al.) 21 September 1993, see entire document. | 1-36 |